PACKAGED MICROELECTRONIC DEVICES AND METHODS OF PACKAGING MICROELECTRONIC DEVICES

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority benefits of Singapore Application No. 200303053-3 filed May 30, 2003, the entirety of which is incorporated herein by reference.

TECHNICAL FIELD

[0002] The present invention is related to packaged microelectronic devices and methods of packaging microelectronic devices. In particular, the present invention relates to packaged microelectronic devices that include image sensor dies.

BACKGROUND

[0003] Microelectronic devices generally have a die (i.e., a chip) that includes integrated circuitry having a high density of very small components. In a typical process, a large number of dies are manufactured on a single wafer using many different processes that may be repeated at various stages (e.g., implanting, doping, photolithography, chemical vapor deposition, plasma vapor deposition, plating, planarizing, etching, etc.). The dies typically include an array of very small bond-pads electrically coupled to the integrated circuitry. The bond-pads are the external electrical contacts on the die through which the supply voltage, signals, etc., are transmitted to and from the integrated circuitry. The dies are then separated from one another (i.e., singulated) by backgrinding and cutting the wafer. After the wafer has been singulated, the individual dies are typically "packaged" to couple the bond-pads to a larger array of electrical terminals that

can be more easily coupled to the various power supply lines, signal lines, and ground lines.

[0004] An individual die can be packaged by electrically coupling the bond-pads on the die to arrays of pins, ball-pads, or other types of electrical terminals, and then encapsulating the die to protect it from environmental factors (e.g., moisture, particulates, static electricity, and physical impact). For example, in one application, the bond-pads can be electrically connected to contacts on an interposer substrate that has an array of ball-pads. The die and a portion of the interposer substrate are then encapsulated with a covering.

[0005] Electronic products require packaged microelectronic devices to have an extremely high density of components in a very limited space. For example, the space available for memory devices, processors, displays, and other microelectronic components is quite limited in cell phones, PDAs, portable computers, and many other products. As such, there is a strong drive to reduce the height of the packaged microelectronic device and the surface area or "footprint" of the microelectronic device on a printed circuit board. Reducing the size of the microelectronic device is difficult because high performance microelectronic devices generally have more bond-pads, which result in larger ball-grid arrays and thus larger footprints.

[0006] Image sensor dies present additional packaging problems. Image sensor dies include an active area that is responsive to electromagnetic radiation. In packaging, it is important to cover and protect the active area without obstructing or distorting the passage of light or other electromagnetic radiation. Typically, an image sensor die is packaged by placing the die in a recess of a ceramic substrate and attaching a glass window to the substrate over the active area to hermetically seal the package. A vacuum is typically drawn to remove air from the gap between the image sensor die and the glass window. An inert gas can then be injected into the gap between the image sensor die and the glass window. One drawback of packaging image sensor dies in accordance with this method is the difficulty of removing dust, moisture, and other contaminants from the gap

between the glass window and the image sensor die. Furthermore, the packaged image sensor dies are relatively bulky and, accordingly, use more space on a circuit board or other external device than other types of dies.

[0007] One existing approach to address the foregoing drawbacks is to attach a window directly to an image sensor die with a window support, such as an epoxy. In this approach a top portion of the window is machined to create a step to receive mold compound. The image sensor die is also attached to a die attach pad, and the bond-pads on the image sensor die are electrically coupled to leads that are positioned proximate to the ends of the image sensor die. The image sensor die, the die attach pad, and the step in the window are encapsulated. This approach, however, has several drawbacks. For example, the package does not effectively transfer heat away from the image sensor die because the leads are positioned proximate to the edge of the package. Moreover, the package has a high profile because the leads project outwardly away from the package. Furthermore, the mold compound does not effectively adhere to the die attach pad, and accordingly, separation can occur. In addition, machining the step in the window adds another procedure and expense to the manufacturing process.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Figures 1-4 illustrate various stages in a method of packaging a microelectronic device in accordance with one embodiment of the invention.

[0009] Figure 1 is a schematic cross-sectional side view of the microelectronic device after a window has been attached to an image sensor die.

[0010] Figure 2 is a schematic cross-sectional side view of the microelectronic device after attaching a plurality of leads to the image sensor die.

[0011] Figure 3 is a schematic cross-sectional side view of a mold apparatus for encapsulating the microelectronic device.

[0012] Figure 4 is a schematic cross-sectional side view of the microelectronic device after forming a plurality of solder balls.

[0013] Figure 5 is a schematic cross-sectional side view of a microelectronic device in accordance with another embodiment of the invention.

[0014] Figure 6 is a schematic cross-sectional side view of a microelectronic device in accordance with still another embodiment of the invention.

[0015] Figure 7 is a schematic cross-sectional side view of a microelectronic device in accordance with yet another embodiment of the invention.

[0016] Figure 8 is a schematic cross-sectional side view of a microelectronic device in accordance with still another embodiment of the invention.

DETAILED DESCRIPTION

A. Overview

[0017] The following description is directed toward packaged microelectronic devices and methods of packaging microelectronic devices. Many specific details of several embodiments are described below with reference to packaged microelectronic devices having image sensor dies to provide a thorough understanding of such embodiments. The present invention, however, can be practiced using other types of microelectronic devices and/or micromechanical devices. Those of ordinary skill in the art will best understand that the invention may have additional embodiments, or that the invention may be practiced without several of the details described below.

[0018] One aspect of the invention is directed to packaged microelectronic devices. In one embodiment, a packaged microelectronic device includes an image sensor die having a first side with a bond-pad, an active area on the first side, and a second side opposite the first side. The device further includes a window at the first side of the image sensor die and a lead mounted to the second side of the image sensor die. The window is radiation transmissive and positioned over the active area of the image sensor die. The lead is electrically coupled to the bond-pad on the image sensor die. The device can also include a removable protective covering attached to the side of the window opposite the image sensor die. The window can be attached to the image sensor die with an

adhesive, and the lead can be attached to the image sensor die with lead-on-chip tape.

[0019] In one aspect of this embodiment, the device further includes a casing over the bond-pad, a portion of the second side of the image sensor die, and a portion of the lead. The casing can include a recess exposing a portion of the lead to the ambient environment. The lead can include an end external to the casing that has an arcuate or other suitable configuration. Alternatively, the ends of the lead can be covered by the casing and a portion of the lead between the ends can be exposed to the ambient environment. The device can further include a ball-pad coupled to the lead and a solder ball on the ball-pad.

[0020] Another aspect of the invention is directed to methods of packaging microelectronic devices. The packaged microelectronic devices include image sensor dies having a first side with a bond-pad, an active area on the first side, and a second side opposite the first side. In one embodiment, the method includes attaching a radiation transmissive window to the first side of the image sensor die, mounting a lead to the second side of the image sensor die, electrically coupling the bond-pad to the lead, and encapsulating a portion of the lead and a portion of the second side of the image sensor die with a casing. In one aspect of this embodiment, encapsulating the lead and the image sensor die includes disposing the window, the image sensor, and the lead in a mold cavity and injecting a mold compound in the mold cavity. The method can further include attaching a removable protective covering over a portion of the window, forming a ball-pad on the lead, and placing a solder ball on the ball-pad.

B. A Method of Packaging a Microelectronic Device

[0021] Figures 1-4 illustrate various stages in a method of packaging a microelectronic device in accordance with one embodiment of the invention. For example, Figure 1 is a schematic cross-sectional side view of a microelectronic device 10 including an image sensor die 20 and a window 40 attached to the image sensor die 20. The image sensor die 20 includes a first side 26 having a plurality of bond-pads 24 and an active area 30 responsive to electromagnetic

radiation. For example, in one embodiment, the active area 30 includes a sensitive area with a plurality of sensor cells. The image sensor die 20 further includes a second side 28 opposite the first side 26 and an integrated circuit 22 (shown schematically) electrically coupled to the active area 30 and the bond-pads 24.

[0022] In one aspect of this embodiment, an adhesive 48 is deposited over the active area 30 on the first side 26 of the image sensor die 20. The adhesive 48 is a transmissive material to permit light and/or other electromagnetic radiation to pass through the adhesive 48 and contact the active area 30. For example, the adhesive 48 can be an optical grade material with a high transparency and a uniform mass density to allow maximum light transmission. The adhesive 48 can also be a highly pure material to minimize contamination and thereby reduce or eliminate the loss of images and/or light scattering. Suitable adhesives 48 include BCB manufactured by Dow Chemical of Midland, Michigan, or other similar materials.

[0023] After the adhesive 48 is deposited, the window 40 is placed on the adhesive 48 and attached to the image sensor die 20 over the active area 30. The window 40 includes a first side 42, a second side 44 opposite the first side 42, a first end 46, and a second end 47 opposite the first end 46. In additional embodiments, the adhesive 48 can be deposited on the second side 44 of the window 40 instead of, or in addition to, the first side 26 of the image sensor die 20. The microelectronic device 10 can also include a removable protective covering 49 attached to the first side 42 of the window 40 to protect the window 40 from scratches and other defects during the manufacturing process.

[0024] Figure 2 is a schematic cross-sectional side view of the microelectronic device 10 after attaching a plurality of leads 60 (identified individually as 60a-b) to the image sensor die 20. In the illustrated embodiment, the leads 60 are generally straight members that include a first portion 62 and a second portion 64 spaced apart from the first portion 62. The first portion 62 is attached to the second side 28 of the image sensor die 20 with an adhesive 68, such as a lead-

on-chip tape or another suitable material. The first portion 62 can be attached to the image sensor die 20 between the first end 46 and the second end 47 of the window 40. A plurality of wire bonds 61 electrically couple the second portion 64 of the leads 60 to corresponding bond-pads 24 on the image sensor die 20. In other embodiments, such as those described below with reference to Figures 5-8, the leads can have other configurations.

[0025] Figure 3 is a schematic cross-sectional side view of a mold apparatus 90 for encapsulating the microelectronic device 10 of Figure 2 in accordance with one embodiment of the invention. In one aspect of this embodiment, the mold apparatus 90 includes an upper mold portion 92 having an upper mold cavity 93 and a lower mold portion 94 having a lower mold cavity 95. The upper mold cavity 93 is configured to receive the image sensor die 20, the window 40, and the wire bonds 61. The lower mold cavity 95 is configured to receive the leads 60. The lower mold portion 94 can also include projections 96 positioned to press the microelectronic device 10 against the upper mold portion 92 to prevent a mold compound 82 from bleeding between the protective covering 49 and the upper mold portion 92. More specifically, the projections 96 are arranged to exert a force against the first portion 62 of the leads 60 in a direction generally normal to the microelectronic device 10. The force is exerted between the first end 46 and the second end 47 of the window 40 so that the force is transferred through the leads 60, the adhesive 68, the image sensor die 20, the adhesive 48, and the window 40 to (a) secure the semi-assembled chip so that during molding the high pressure mold compound is eliminated or greatly reduced, and (b) increase the stability of the microelectronic device 10 within the mold apparatus 90. Accordingly, the mold compound 82 is introduced into the mold apparatus 90 and flows around the microelectronic device 10 to form a casing 80, which encapsulates the image sensor die 20 and a portion of the leads 60. In this embodiment, the projections 96 create a plurality of recesses 84 in the casing 80 over the first portion 62 of the leads 60. In other embodiments, the mold apparatus 90 may not include the projections 96. The microelectronic device 10

can be heated before and/or after encapsulation to cure the adhesive 48 and/or the mold compound 82.

[0026] Figure 4 is a schematic cross-sectional side view of the microelectronic device 10 after forming a plurality of solder balls. After removing the microelectronic device 10 from the mold apparatus 90 (Figure 3), a plurality of ball-pads 70 are formed in corresponding recesses 84 in the casing 80. The ball-pads 70 can be formed on and electrically coupled to the first portion 62 of the leads 60. Next, a plurality of solder balls 72 are formed on corresponding ball-pads 70 and accordingly electrically coupled to corresponding bond-pads 24 on the image sensor die 20. In other embodiments, the microelectronic device 10 may not include ball-pads 70. For example, the solder balls 72 can be formed directly on the first portion 62 of the leads 60. In any of these embodiments, the solder balls 72 can be arranged in arrays for attachment to circuit boards or other devices. The protective covering 49 (Figure 3) can be removed from the window 40 at the end of the packaging process.

[0027] One feature of the microelectronic device of the illustrated embodiment is the leads are positioned proximate to the image sensor die and the center of the device. An advantage of this feature is that the microelectronic device efficiently transfers heat away from the image sensor die and center of the device. Another feature of the microelectronic device is the placement of the mold compound against the second side of the image sensor die. An advantage of this feature is the improved reliability of the microelectronic device because the mold compound adheres to the image sensor die.

C. <u>Other Packaged Microelectronic Devices</u>

[0028] Figure 5 is a schematic cross-sectional side view of a microelectronic device 110 in accordance with another embodiment of the invention. The microelectronic device 110 can be similar to the microelectronic device 10 described above with reference to Figure 4. For example, the microelectronic device 110 includes an image sensor die 20, a window 40 attached to the image sensor die 20, and a casing 80 covering a portion of the image sensor die 20.

The microelectronic device 110 further includes a plurality of leads 160 (identified individually as 160a-b) coupled to the second side 28 of the image sensor die 20 and electrically coupled to corresponding bond-pads 24. The leads 160 include a first portion 162 coupled to the image sensor die 20 and a second portion 164 external to the casing 80. The second portion 164 has a generally arcuate configuration for attachment to an external device. More specifically, the second portion 164 projects outward away from the casing 80, curves downward, and then curves inward like a "C." An advantage of the curvature of the second portion 164 is the improved robustness of the leads 160 because they do not have sharp angles. Accordingly, the leads 160 are less likely to bend or break if the microelectronic device 110 is dropped. In other embodiments, the casing 80 may not include recesses 84.

[0029] Figure 6 is a schematic cross-sectional side view of a microelectronic device 210 in accordance with another embodiment of the invention. The microelectronic device 210 can be similar to the microelectronic device 10 described above with reference to Figure 4. For example, the microelectronic device 210 includes an image sensor die 20, a window 40 attached to the image sensor die 20, and a casing 280 enclosing a portion of the image sensor die 20. The microelectronic device 210 further includes a plurality of leads 260 (identified individually as 260a-b) coupled to the second side 28 of the image sensor die 20 and electrically coupled to corresponding bond-pads 24. The leads 260 include a first portion 262 attached to the second side 28 of the image sensor die 20 and a second portion 264 external to the casing 280. The second portion 264 has an "L" shaped configuration with a first segment 265a extending downward and a second segment 265b projecting inward in a direction generally parallel to the image sensor die 20. An advantage of the "L" shaped configuration of the leads 260 is that it reduces the profile of the device 210 because the first segment 265a of the second portion 264 projects downwardly as opposed to away from the device 210. In additional embodiments, the leads 260 can have other configurations for attachment to external devices.

[0030] Figure 7 is a schematic cross-sectional side view of a microelectronic device 310 in accordance with another embodiment of the invention. The microelectronic device 310 can be similar to the microelectronic device 10 discussed above with reference to Figure 4. For example, the microelectronic device 310 includes an image sensor die 20, a window 40 attached to the image sensor die 20, and a casing 380 covering a portion of the image sensor die 20. The microelectronic device 310 further includes a plurality of leads 360 (identified individually as 360a-b) coupled to the second side 28 of the image sensor die 20 and electrically coupled to corresponding bond-pads 24. The leads 360 include a first portion 362 coupled to the image sensor die 20 and a second portion 364 projecting away from the image sensor die 20. In the illustrated embodiment, the second portion 364 includes a first segment 365a generally coplanar with the first portion 362 and a second segment 365b coupled to the first segment 365a. The first and second segments 365a-b are oriented transversely relative to each other. The casing 380 includes a plurality of recesses 386 over the first and second segments 365a-b to expose the segments 365a-b to the ambient environment for attachment to an external device. The recesses 386 can be formed by removing portions of the casing 380, or a mold cavity can form the casing 380 in such a way as to expose the first and second segments 365a-b.

[0031] One feature of the microelectronic device 310 of the illustrated embodiment is that the leads 360 do not project from the casing 380. An advantage of this arrangement is that the microelectronic device 310 has a lower profile and is more robust because the leads 360 are less likely to break or bend.

[0032] Figure 8 is a schematic cross-sectional side view of a microelectronic device 410 in accordance with another embodiment of the invention. The microelectronic device 410 can be similar to the microelectronic device 10 discussed above with reference to Figure 4. For example, the microelectronic device 410 includes an image sensor die 20, a window 40 attached to the image sensor die 20, and a casing 480 covering a portion of the image sensor die 20. The microelectronic device 410 further includes a plurality of leads 460 (identified

individually as 460a-b) coupled to the second side 28 of the image sensor die 20 and electrically coupled to corresponding bond-pads 24. The leads 460 include a first portion 462 coupled to the image sensor die 20, a second portion 464 projecting away from the image sensor die 20, and a first bend 466a between the first portion 462 and the second portion 464. The second portion 464 includes a first segment 465a and a second segment 465b coupled to the first segment 465a at a second bend 466b. The first segment 465a is generally parallel to the first portion 462 and projects at least partially beyond a bottom surface 481 of the casing 480. Accordingly, the first segment 465a is exposed to the ambient environment for attachment to an external device. The second segment 465b is transverse to the first segment 465a and can also be exposed to the ambient environment.

[0033] From the foregoing, it will be appreciated that specific embodiments of the invention have been described herein for purposes of illustration, but that various modifications may be made without deviating from the spirit and scope of the invention. Accordingly, the invention is not limited except as by the appended claims.